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On the Early Development of Stagnicola Kingi (Meek)

The Utah Ribbed Snail

BY

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ON THE EARLY DEVELOPMENT OF STAGNICOLA KINGI (MEEK), THE UTAH RIBBED SNAIL[1] [2]

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General interest in the subject of molluscan embryology has continued in part because of the relation of its problems and processes to those of adult anatomy and physiology and in part because of its promise of light on the dynamic, developmental process itself. Attention was called to the present form because of its earlier uncertain taxonomic position, and its restriction to the Great Basin area, where, although wide-spread and abundant in Tertiary and Quaternary times, it is now all but extinct. (Cf. Chamberlin, 1932.) It seems desirable to place on record the following summary of the early embryology of this form which promises to be increasingly significant in studies on the historic and ecologic aspects of the fauna of the region.

MATERIALS AND METHODS

The adult specimens of *Stagnicola kingi*, the eggs of which were used in the present investigation, were collected in Utah Lake in which they now live apparently only on the west side along a quarter mile length of shore, where springs arising near the present lake level keep the water fresher than it is elsewhere. The specimens collected at this locality were transported in jars containing lake water to the laboratory where the animals were gradually transferred to city water in all-glass aquaria of one-gallon capacity. Not over fifty snails were placed in any one aquarium. The aquaria were placed in a sunny window of a room whose temperature varied from 16 degrees to 29 degrees Centigrade. Water was changed daily by allowing a fresh supply to trickle gently into the container from which about three-fourths of the stale water had been removed. Occasionally a drop or two of a solution of calcium hydroxide was added to the water to neutralize the carbonic acid given off by the animals. Under these conditions the

[1]Abridgment of thesis submitted to the University of Utah, in partial fulfillment of the requirements for the degree of Master of Arts.

[2]My sincere thanks is due to Dr. R. V. Chamberlin, who suggested the problem, and whose careful supervision and generous interest have made the work enjoyable. I am also indebted to Mr. W. W. Newby for various suggestions and services given during the investigation.

snails thrived on a diet of lettuce and deposited egg capsules with more or less regularity. The largest number of eggs were obtained in July, August, and November, but during the latter month the snails were kept under summer temperature conditions. Most egg masses were deposited at night or early in the morning. Upon discovery these were transferred from the aquaria to Syracuse watch glasses containing tap-water in which they were observed and allowed to develop. For purposes of study the embryos were dissected and preserved.

THE EGG AND ITS ENVELOPES

The habits of oviposition and the character and arrangements of the envelopes in which the eggs are enclosed are essentially similar to those of other aquatic Pulmonata.

The unsegmented ovum itself is spherical in shape and varies in diameter from 90 to 130 microns, the average diameter probably lying in the neighborhood of 110 to 114 microns. The ovum varies from a straw to a grayish-yellow color, this color being due to uniformly distributed yolk globules. Associated with these rather coarse globules are much finer globules, probably also yolk. The lighter colored nucleus occupies about one-third of the mass of the living egg and is centrally located until just before the extrusion of the first polar body when it assumes an eccentric position.

The ovum or embryo is immediately surrounded by a semi-fluid, albuminous-like coat which, in turn, is enclosed by a shell membrane, the inner capsule. This capsule can be separated into an inner thin, tough, somewhat elastic portion and an outer laminated portion. These inner capsules are broadly ellipsoidal with one or both ends evenly rounded or somewhat pointed. Each ranges in length from 0.33 mm. to 1.43 mm. and in transverse diameter from 0.27 mm. to 0.82 mm., the averages of 162 specimens being respectively 1.15 mm. and 0.71 mm.

The inner capsules are arranged in a gelatinous matrix, usually in two or three fairly regular and parallel rows. The number in each matrix varies from two to twenty-four, the average for seventy-three capsules being nine eggs. The matrix is of a stringy gelatinous consistency. It is surrounded by a thick, indistinctly-laminated outer capsule which, at the time of deposition, has a turbid appearance but in the course of ten to twenty minutes this turbidity disappears and the capsule becomes transparent or nearly so.

Occasionally more than one embryo was found enclosed within an inner capsule. Of 193 egg masses examined, seven exhibited such a

condition. Eighteen inner egg capsules were involved in these cases, four of which contained four embryos each while the remainder contained only two embryos each. In one case in which four embryos were involved the development was followed through. Growth proceeded in the typical way, but twenty-three days instead of the usual fourteen to sixteen were required to complete development to the point of hatching. The inner capsules containing two embryos each also ruptured in somewhat longer than usual time. No data were secured indicating that these individuals were derived from one egg.

A number of cases in which inner capsules occurred without any evident ova within them were noted in the course of this study. About one-half of these capsules were of normal size; the others varied from one-half to one-third normal size. The capsules in a few cases were not held turgid by the contents, but presented numerous folds on their surfaces.

SEGMENTATION

Both polar bodies are small and clear in appearance, the first, as usual, being the larger of the two. The first normally rests upon the second polar body. These bodies may or may not remain in contact with the egg during cleavage.

The Primary Cleavages: The first two cleavages are equal, but with the third, which gives rise to the eight-cell stage, it becomes unequal and markedly spiral. The initial cleavages proceed much as they do in other members of the Pulmonata. About one-half hour after the extrusion of the second polar body, the ovum becomes slightly ellipsoidal with the surfaces somewhat flattened at animal and vegetal poles. Abruptly following this, a broad furrow or depression appears, first at the animal pole, encircling the egg in a plane of the animal-vegetal axis and finally pinching apart two spherical and equal blastomeres in which the nuclei are situated somewhat eccentrically toward the animal pole. The daughter cells soon become flattened on their contiguous sides and assume an almost hemispherical shape. Between them, in the meantime, a temporary cleavage cavity appears and increases slowly in size until just before the next cleavage, when it suddenly disappears. Similar cavities have been reported at the corresponding stage by Holmes, Kofoid, and Wierzejski in *Planorbis*, *Agriolimax*, and *Physa* respectively.

Following closely upon the attainment of the maximal flattening, the blastomeres constrict at the middle in a plane at right angles to the first one. Constriction progresses rapidly and at the end of approximately fifteen minutes four distinct blastomeres are visible. Fre-

quently the division of one of the two primary blastomeres is slightly in advance of that of the other. Moreover, in the course of the second division, the axes of these cells are often bent from their parallel position, and a slight torsion becomes evident. As a result, one of each pair of daughter cells comes to lie somewhat higher than the other.

As the blastomeres of the four-cell stage of *S. kingi* undergo flattening on the sides of mutual contact, a temporary cleavage cavity again develops. In some cases it becomes quite large, although, as a rule, it remains small. A similar cavity is present in *Stagnicola nuttalliana* and it has also been reported for *Agriolimax*, *Planorbis*, and *Physa*. The relationship of the blastomeres of this stage to each other is illustrated in Figures 7 and 8.

The Eight Cell Stage: The direction of the third cleavage is clockwise or dexiotropic. The four micromeres may or may not be derived from the parent blastomeres at the same time. Usually, however, when one of the micromeres has appeared as a distinct cell, spindles are visible in the other three undivided blastomeres. (Fig. 9.) These spindles were observed to lie in a dexiotropic direction in *S. kingi*, as reported in *Agriolimax*. In *Physa* and *Planorbis* they are said to arise laeotropically. In size the micromeres are approximately equal. They are about one-third as large as the macromeres. The same appears to be true in case of embryos of *S. nuttaliana*. A cross furrow also arises in the eight-cell stage. The difference in position between this cross furrow of the first quartet and the vegetal cross furrow of the original blastomeres is about forty-five degrees.

Simultaneously with the flattening of the originally rounded blastomeres a small cleavage cavity again forms, only to disappear at the next cleavage. Such a cavity was observed also in *S. nuttalliana*. Other workers have indicated a similar cavity in *Planorbis*, *Physa* and *Agriolimax*.

The Twelve Cell Stage: Starting with the twelve-cell stage, observations on segmentation are all on preserved material. Following the eight-cell stage, one of the quartet divides to form four daughter cells, while the other quartet remains inactive. Thus there arises a stage in which twelve cells are present instead of the expected sixteen. A similar twelve-cell stage has been reported to be a phase in the development of *Planorbis*, *Lymnaea*, and *Physa*. In all of these cases the twelve-cell stage is probably the result of the cleavage of the residual macromeres to yield the second quartet. The cells of the second quartet lie in the grooves between the residual macromeres and alternate with the cells of the first quartet (See Fig. 12) as reported in *Physa and Planorbis*.

After the cleavage process is complete the usual cleavage cavity appears. At this stage it takes on a more permanent nature, and retains its identity through the succeeding cleavages. In all cases it is relatively small and has a somewhat eccentric location in the direction of the animal pole.

The duration of the twelve-cell stage is extended, the period of rest lasting beyond two hours. A briefer rest period in which there is no mitotic activity also occurs at the eight-cell stage.

The Twenty-four Cell Stage: At the end of this rest period in the development of *S. kingi*, the blastomers undergo further division, the result of which is an embryo of twenty-four cells. (See Fig. 13.) The four central cells shown in the figure appear to be the residual macromeres. Surrounding them are other cells apparently belonging to the second and third quartets of ectomeres. The total number of cells visible in the figure is twelve. All of the cells examined in the embryos of this stage were in a state of inactivity. At this phase of development the cleavage cavity, relative to the size of the embryo, is smaller than in the preceding stage.

Later Cleavage Stages: The cleavage stages following the twenty-four cell stage were not followed out in detail. Characterizing these later stages is a landmark figuring prominently in the development of Gastropoda in general, the so-called "molluscan cross." It stands out conspicuously on the surface of the animal pole because of the contrast of its small cell components with adjacent cells of larger size. Preceding the formation of the gastrula, the cleavage cavity disappears. In its place and perhaps serving the same function, appear a number of intercellular spaces between the cells at the animal pole. Some of these become large and communicate with neighboring cavities. The contents of these cavities appear refringent. Occasionally the contents are in time extruded and may be seen as masses in the surrounding coat in fresh egg masses. Just before gastrulation proper these cavities become either markedly reduced in size or disappear altogether.

The Gastrula Stage: When segmentation has progressed beyond one hundred cells, the embryonic mass begins to flatten more rapidly. The micromeres, increasing in number, crowd toward the vegetal pole of the embryo and thereby force the macromeres to the interior. Closely following the invagination of the vegetal surface of the embryo, the animal pole flattens and the embryo assumes the form of a cushion or thickened disk. A pit-like depression appears eccentrically on the vegetal surface and from this a broad shallow furrow extends across the center of the surface to the periphery. Concomitantly with the appear-

ance of the groove, the embryo takes on a markedly bilateral symmetry. The cells making up the ectodermal wall of the gastrula appear uniform in size and fairly symmetrical in arrangement. They are clearer in appearance than those in the central positions of the vegetal surface. No cleavage cavity is now present. (See Fig. 15.)

In the later part of the gastrula stage, marked rotation of the embryo occurs. This rotation is produced as a result of the activities of cilia acquired by certain cells at the edge of the disk. The long, groove-like blastopore, similar to that of *Lymnaea*, *Planorbis*, *Physa*, and others, remains open for some time but its ultimate fate was not ascertained.

Trochophore: The typically flattened, rapidly revolving gastrula gradually thickens. The clear cells of the animal pole increase in number, while the endoderm cells, proliferating at a somewhat slower rate, crowd the former cells from within, the result being that the embryo assumes a broadly hemispherical or pyramidal shape. Simultaneously, the furrow of the blastopore narrows through the approximation of the limiting ridges which meet in the mid-line and fuse anteriorly, until, finally, a short narrow slit at the center of the oral surface is all that is left of the groove. When the embryo has attained a bell-shaped form, the stomodaeal invagination appears in the flaring portion of the bell opposite the rounded apex of the pyramid. The orifice of the invagination is circular in outline.

The cells making up the outer surface of the Trochophore appear fairly uniform in size and relatively regular in arrangement. The cells of the entoderm are at this time slowly enlarging, probably as a result of the absorption of albuminous material surrounding the embryo. Cells bearing cilia are located at the edge of the bell along a portion of its circumference, but apparently not completely around the edge. This arrangement of cilia may account for the fact that the direction of rotation is in a plane at right angles to the broad transverse axis of the embryo.

As the stomodaeal invagination gains depth, the beginning of a shallow invagination appears at the posterior end of the embryo. This is the primordium of the shell gland. (See Fig. 16.) The cells of this portion of the embryo have begun to assume their columnar form, but have not yet commenced secretion. In that portion of the embryo opposite the stomodaeum, the cells of the ectoderm are in direct contact with the enlarging entoderm cells. At the sides, however, they are separated by cells making up the beginning mesoderm. These cells are arranged in bands extending posteriorly from the angles of the stomodaeal invagination.

Concomitantly with the appearance of the beginning of the shell-gland invagination and the mesodermal band, the prototroch or velum becomes evident. Its constituent cells bear cilia and extend laterally on each side of the stomodaeum and then posteriorly toward the shell-gland at the opposite pole of the embryo. These later developments are, in reality, characteristic of an embryo further advanced than the Trochophore as they grade into and become more prominent in the stage next to be discussed.

Post-Trochophore Stage: Characterizing this stage, which is reached by the third day, are the externally conspicuous foot, velum, mouth, and shell-gland. Internally the enteron, larval nephridia, radular sac, and ganglionic mass are differentiated. (Fig. 17.)

The contour of the embryo is now almost spherical but as development proceeds there is a general antero-posterior elongation of the body. The broadly oval to round orifice of the mouth breaks the median, sub-spherical surface of the embryo at its anterior end. Surrounding the opening itself is a noticeable ridge. To the right and left of the mouth, running ventro-posteriorly with respect to it, a ridge of rather large cells is evident, these ridges constituting the velum or "prototroch." The velum, in general, outlines an area on the embryo similar to the conventional shape of a heart, with the mouth located outside the area in the basal notch. The area bounded by the velum in this form is important in that it is the region in which the eyes, tentacles, cerebral ganglia and other structures arise.

The foot at this stage appears as a slight median bulge just ventral and posterior to the mouth, as it does in *Physa*, *Planorbis*, and *Lymnaea*. The bulge is at first only slightly bilobed in character, but later assumes a markedly bilobed appearance with a distinct ridge extending between the two halves. The cells of the foot are columnar. Many of them, especially those of the anterior portions, are ciliated.

The shell gland, referred to more in detail below, is now conspicuous. It appears as an invagination at the posterior end of the body.

The entoderm cells at this time appear loosely aggregated in a subspherical mass in which a central cavity may or may not be distinguishable. The cells are rounded in contour, large in size, and are greatly vacuolated. The contents of these vacuoles, similar to the extra-embryonic albuminous material, was little affected by the stains employed. As development proceeds, small cells come to occupy positions between the larger cells.

The stomodaeum appears as a short, blunt tube extending from the mouth to the region of the entodermal cells. The walls are composed of columnar cells with distinct nuclei. The lumen is narrow as reported

in *Lymnaea*, the tube ends in a short, reflected caecum which appears to be the radular sac and arises as a ventral out-pouching of the floor. The sac is single, not double as reported in *Physa*, and arises when the shell gland is first invaginated. Its walls are composed of long, columnar cells. The refringent bodies which become the radular teeth are not present in the cavity at this time.

The giant cells of the larval nephridia, apparently of mesodermal origin, may be seen on each side of the median sagittal plane. Other parts of the excretory system have not yet developed. In the giant cells, all of which have conspicuous nuclei, a portion of the cytoplasm is becoming hollowed out to form a tube.

The primordia of the cerebral ganglia appear as widely separated proliferations beneath the ectoderm. The proliferating cells on each side are in the head-region about midway between the median sagittal plane and the lateral velar ridges. The cells are oval in outline and are arranged in a compact mass. Their nuclei are relatively large. Rudiments of eyes or tentacles are not yet distinguishable.

The Time Element: By the time the embryo has reached the typical Post-Trochophore phase of development at room temperature, about four days or about 96 hours have elapsed. In general, this time is distributed as follows:

1st day—Egg deposited, segmentation.

2nd day—Gastrula, embryo begins to revolve.

3rd day—Trochophore to Post-Trochophore.

4th day—Post-Trochophore.

Embryos allowed to develop at room temperature beyond the Post-Trochophore stage were found to hatch in fourteen to sixteen days from the time of deposition of the eggs.

Increase in temperature was found to influence the rate of development. Embryos incubated at 27 degrees Centigrade had developed well into the Trochophore stage by the end of the second day. They were seen to be typical Post-Trochophores at the beginning of the third day. These embryos which were allowed to complete development were found to hatch about four to six days earlier than those allowed to develop at room temperature, or in nine to eleven days, instead of the usual fourteen to sixteen days.

Notes on the Development of the Shell: The shell-gland is one of the first larval structures to make its appearance. It becomes evident when the velum is taking the form characteristic of the Post-Trocho-

phore stage (Fig. 16) and before either eyes or tentacles have made their appearance. The cells of the invaginated structure, with their surfaces slightly rounded, have begun to assume a columnar form.

In the Post-Trochophore stage of development the characteristic shell-gland may be recognized. In the present form it is of the open type. At this time it is evident as a postero-dorsal invagination of the ectoderm at the end opposite the stomodaeum. The invagination is relatively deep, with a narrow lumen which occasionally contains a refringent secretion probably corresponding to the so-called "shell-plug" of Lankester (1874, 1875). Toward the center of the embryo the gland makes contact with the entoderm cells and is partly enveloped by them. (See Fig. 19.)

As development progresses, the shell-gland shifts to a slightly more dorsal position and becomes more shallow (Fig. 20). As Figures 19 to 21 indicate, there is a steady encroachment of entoderm cells into the region previously occupied by the shell-gland. The cells of the gland, meanwhile, have begun their secretory activities. As a result a thin cuticular membrane surrounds the mouth of the invagination, the primordium of the shell. (See Fig. 20.) The shell is circular or broadly oval in outline.

With the further increase in the number of cells in the posterior region of the embryo, and the further flattening of the gland, the secreting cells occupy more of the posterior surface of the embryo. While the wall of the shell gland area at first appears thick, a thinning of the wall in the central area becomes apparent. Simultaneously with this thinning, the walls at the edge of the gland appear markedly thickened to form a peripheral ridge, the primordium of the mantle edge. (Fig. 21.) In subsequent development the area of the shell is increased as a result of the secretory activities of the cells of the mantle edge.

The cap-like primordial shell lies in mid-line at the posterior end of the animal. Shortly after the shell-gland becomes flattened it shifts somewhat to the left, this displacement being followed by the beginning of the coiling of the shell. Slight at first, the coiling rapidly increases in extent. (See Figs. 24 and 25.) Figure 26 represents the shell as it appears shortly after the Post-Trochophore stage. At this time the bilobed bulge of the foot is conspicuous and is covered with cilia in a constant state of motion, while eye pigment has appeared and the tentacles are visible as slight elevations of the head region just dorsal to the ciliated velum.

A somewhat later stage is represented in Figure 27, at which time the mantle margin appears as a heavy collar situated at the periphery

of the shell and a distinct invagination of the pulmonary cavity is evident. The shell of a slightly older snail is shown in Figure 29 in which a distinct beginning of coiling may be noted. The shell illustrated in Figure 30 has undergone considerable bending in the form of a spiral. It is very ovate, and is broader than long. The beginning of the whorl of the animal is situated upward toward the left, the aperture being at the right. The columella primordium is somewhat twisted. The body of the first whorl is laterally evenly rounded and appears perfectly smooth, save for fine growth lines marking the portion of the shell surrounding the aperture. No spire is yet present. The foot at this time has taken on more of the adult characteristics. It has lost its bilobed appearance and cilia have disappeared from the greater portion. The now more marked invagination of the pulmonary chamber is sac-like and has an oval opening.

The animal now enters upon a phase of development leading to the hatching period. The shell, in response to the unequal growth of the integument, has undergone marked torsion. It is broadly ovate, slightly longer than broad and is much longer than in the preceding stages. A spire is absent although the initial coil of the shell is elevated somewhat above the wider adjacent whorl. The aperture is almost as long as the shell but, relatively, is noticeably narrower than in the preceding stage. The columellar margin is somewhat reflected and the columella appears somewhat twisted in front. The beginning of an umbilicus has made its appearance. While the greater extent of the first whorl appears smooth, marked lines of growth are apparent on the remainder of the shell. In some shells the aggregation of the lines of growth in groups suggest a primitive tending to the formation of costae that are characteristic of the adult shells of this species. (Figures 32 and 33.)

The foot of the now larger animal is now of the adult type and the animal as a whole is taking on a truly lymnaeid appearance. The tentacles are assuming a triangular appearance and at their bases the eyes have acquired highly refractile bodies, the lenses. The buccal apparatus, not functional in previous stages, is now active, there being an occasional operation of jaw and radula as the animal moves about inside the egg-membrane. The liver derived from some of the large entoderm cells, is lobed with cells still relatively large.

The appearance of the shell at the time of hatching is indicated in Figure 34. It is composed of from one and one-half to two complete whorls. It is ovate and longer than broad, with the initial whorl elevated somewhat above the succeeding whorl. The aperture, oval to

elliptical in outline, is about four-fifths the length of the shell. The columella is markedly twisted in front. The lines of growth are marked on the surface of the shell. Costae do not appear until the animal has entered upon its post-embryonic phase and calcium carbonate has begun to be deposited underneath the periostracum. Conspicuous oval bodies in the substance of the mantle collar, similar to some aggregated in triangular masses in the posterior section of the foot, probably bear a relation to the secretory activities of the mantle. A discussion of the activities of the cells of the mantle edges must be deferred pending the outcome of detailed investigations.

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EXPLANATION OF PLATES

Meanings of Abbreviations

ac. arm of Molluscan Cross.
an. aperture; animal pole.
ap. blastoporic depression.
bd. cilia.
c. capsular cavity.
cc. cleavage furrow.
cf. cerebral ganglia.
cg. capsule laminae.
cl. anus.
clc. cleavage cavity.
cr. cross furrow.
ct. cytoplasm.
d. digestive gland.
e. eye; entodermal area.
ec. extension of capsule.
em. embryo.
en. entodermal cells.
f. foot.
l. invagination of pulmonary cavity.
lcc. laminated covering of shell membrane
lg. lines of growth.
ln. larval nephridium.
mac. mantle edge.
me. macromere.
mic. mesoderm.
m. micromere.
n. nucleus.
pb. polar body.
pbt. blastoporic trough.
1q. first quartet cell.
2q. second quartet cell.
r. radular sac.
s. mitotic spindle; suture.
sg. shell gland.
sh. shell.
sm. shell membrane.
sr. stomodaeum.
t. tentacle.
vl. suture.
st. umbilical primordium.
up. velum.
v. velar line.

PLATE I.

All figures except number one of this plate are camera lucida drawings of living material. Figure 1 is a direct projection of a capsule containing rotating embryos in the Post-Trochophore stage. Spindles diagrammatic.

1. Optical section of outer capsule seen from unattached side. The relationship of the envelopes are indicated. Projection of scale to which figure is drawn.
2. Camera lucida projection of micrometer scale to which figures three to eleven of this plate are drawn.
3. Fertilized ovum just before the first cleavage.
4. Early stage of the first cleavage.
5. First cleavage. The blastomeres have separated and have begun to flatten.
6. First cleavage. Blastomeres have almost reached maximum flattened condition. Temporary cleavage cavity has appeared.
7. Second cleavage, polar view showing cross furrow.
8. Second cleavage, lateral view.
9. Third cleavage; beginning of division.
10. Third cleavage, polar view showing relative sizes and positions of the macromeres and micromeres.
11. Third cleavage, lateral view.

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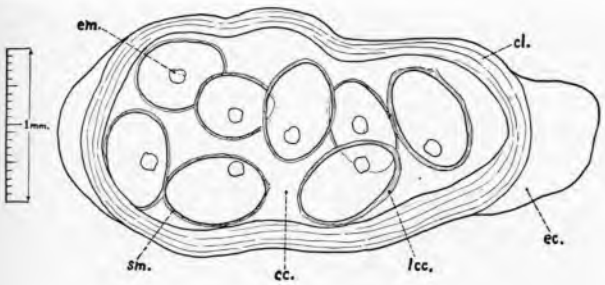

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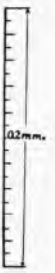

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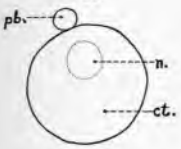

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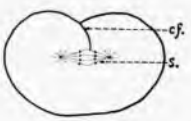
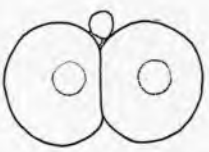


5.



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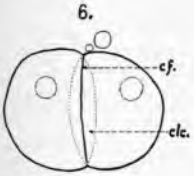

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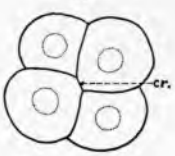

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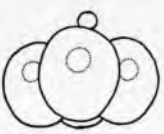

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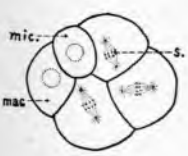

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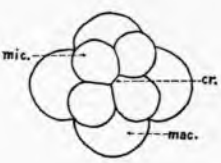

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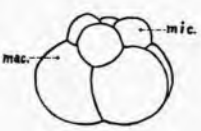
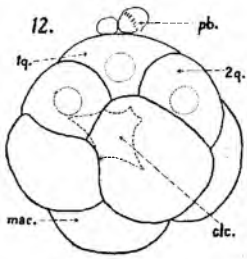


PLATE II.

All figures of prepared material. Camera lucida outlines; details free-hand. Figures 19 to 22 are micro-projections.

12. Twelve cell stage, lateral view.
13. Twenty-four cell stage.
14. Later cleavage stage, showing Molluscan Cross at the animal pole.
15. Gastrula stage, lateral view.
16. Advanced Trochophore, antero-dorsal view.
17. Post-Trochophore, lateral optical section. Scale.
18. Scale to which Figures 12 and 16 are drawn.
19. Shell-gland of Post-Trochophore, median sagittal section.
20. Shell-gland of later stage, median sagittal section.
21. Flattened shell-gland of later stage, median sagittal section.
22. Scale to which Figures 19 to 21 are drawn.
23. Shell primordium of Post-Trochophore, dorsal surface view. Scale, Figure 17.
24. Embryo in advanced stage of development, right lateral view, showing displacement ofshell to left.
25. Embryo of same stage, left lateral view.
26. Embryonic shell of stage corresponding to that of Figures 24 and 25.

26a. Scale to which Figures 24 to 26 are drawn.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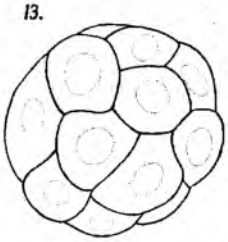
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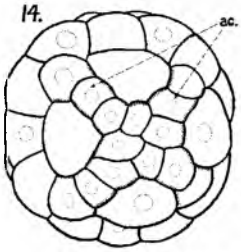
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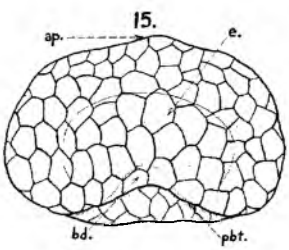
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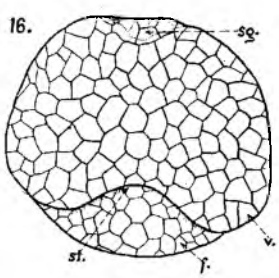
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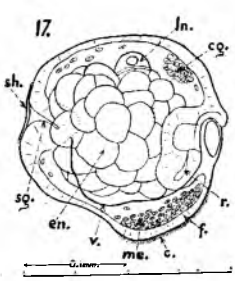
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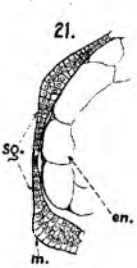
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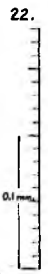
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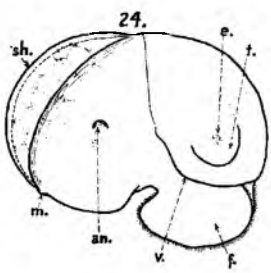
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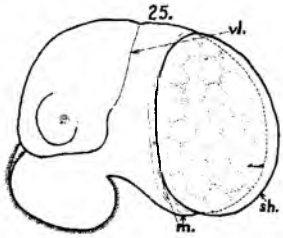
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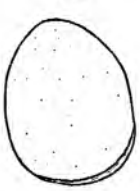
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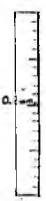
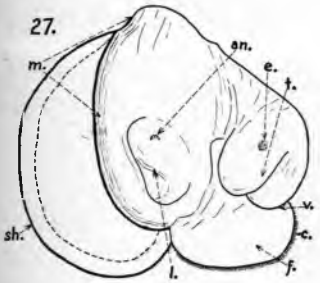

26a.

PLATE III.

All figures of prepared material. Camera lucida outlines; details free hand.

27. Advanced embryo, lateral view.
28. Shell of embryo of stage shown in Figure 27.
29. Shell of more advanced embryo. Scale, Figure 38.
30. Shell at beginning of the coiling process.
31. Same shell as that of Figure 30. View of body whorl.
32. Shell just before hatching of the snail, showing aperture.
33. Same shell, showing principal whorl.
34. Shell at the time of hatching of the snail.
35. Shell just after hatching of the snail, seen from above.
36. Shell shortly after hatching of the snail, showing principal whorl.
37. Shell shortly after hatching of the snail, showing aperture.
38. Scale to which Figures 29 to 36 are drawn.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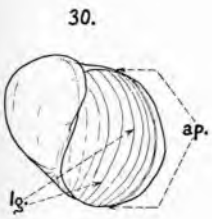
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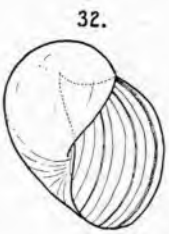
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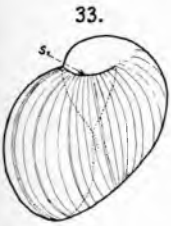
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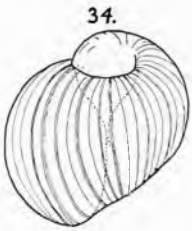
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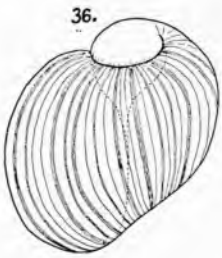
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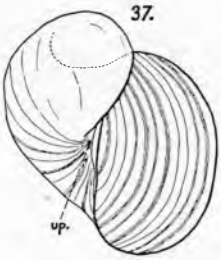
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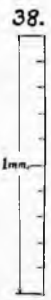
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